

Report for 2002WA19G: Using environmental tracers to improve prediction of nonpoint pollutant loadings from fields to streams at multiple watershed scales

- Conference Proceedings:
 - Allen-King, R., 2003, Ground and Surface Water Contributions to Chemical Mass Discharge: Field to Basin Scales, Keynote Address, "in" Abstracts, 4th Symposium on the Hydrogeology of Washington State, April 8-10 2003, Tacoma, WA. (<http://www.ecy.wa.gov/events/hg/index.htm>)
 - Simmons, Amy N., Richelle M. Allen-King, C. Kent Keller, and Jeffrey L. Smith, 2003, Dissolved pesticide mass discharge in a semi-arid dryland agricultural watershed at the field and basin scale. Proceedings of the Fourth Symposium on the Hydrogeology of Washington State, April 8-10, 2003, Tacoma, Washington, p. 78. http://www.ecy.wa.gov/events/hg/abstracts_talks.htm
 - Suzuki, K., C. K. Keller, and J. Vervoort, 2004. Weathering in and calcium losses from semi-arid agricultural landscapes: Insight from strontium isotope ratios, in EOS Transactions, American Geophysical Union 85(47), F873.
 - Wannamaker, C. N., A. Goodwin, C. K. Keller, R. Allen-King, and J. L. Smith, 2004. Edge of field nitrate loss and oxygen-18 dynamics in a dryland agriculture setting, in EOS Transactions, American Geophysical Union 85(47), F912.
- Other Publications:
 - Keller, C.Kent, 2003, Using environmental tracers to understand agrichemical transport pathways to Palouse surface water, Invited Presentation to WSU Water Quality Research and Extension Colloquium, April 24, 2003, Washington State University, Pullman, WA.
 - Simmons, A.N., L.L. Bissey, R.M. Allen-King, C.K. Keller, and J.L. Smith, 2003, Estimated dissolved agricultural mass discharges using environmental tracers in a semi-arid dryland agricultural watershed (Abstract), "in" Abstracts with Programs, Geological Society of America Annual Meeting, November 2-5, 2003, Seattle, Washington, Abstracts with Programs 34(7), Paper No. 130-12, p. 316.
- Dissertations:
 - Simmons, Amy N., 2003, Dissolved Pesticide Mass Discharge in a Semi-arid Dryland Agricultural Watershed at the Field and Basin Scale, M.S. Dissertation, Department of Geology, Washington State University, Pullman, Washington, 165 pp.

Report Follows

PROBLEM AND RESEARCH OBJECTIVES

Among the most serious consequences of agricultural-N application perturbations is N loading of terrestrial and coastal ocean waters with associated effects on water quality, aquatic and marine habitat and productivity, and other environmentally critical variables and processes. In the US, tens of thousands of river and shore reaches are considered impaired by the EPA, and many of these impairments are believed to be attributable to agricultural non-point sources. This means that it is important to understand how agricultural practices are related to streamwater N loading, in various climate/cropping associations.

In this work we are studying how field-scale processes influence delivery of nitrogen (primarily as dissolved nitrate, NO_3) to streams. We have hypothesized that in our semiarid dryland farming region, stream NO_3 discharge, from field and small catchment to basin scales, is principally controlled by the response of field-scale flow and transport processes to drainage regime and strongly seasonal hydrology. We are testing this hypothesis by expanding our ongoing study of field-scale processes to include undrained settings, and developing a spatially- and temporally-detailed ^{18}O data set which can be used, in parallel with geochemical data sets, for simultaneous isotope and geochemical hydrograph separations at multiple watershed scales. The isotope data are needed to identify water sources (“new” vs “old”). Used in combination with pathway information from the geochemical tracers, they will help us understand how temporal evolution of soil NO_3 distributions is related to transport times to streams.

The concentration and mass discharge of an environmental tracer at a watershed gauging station are the averaged consequences of hydrologic processes across the entire watershed. The watershed-scale averaging property of stream discharge and streamwater isotope geochemistry has been used for decades to interpret variation of sources of streamflow over the course of hydrologic events. These signals, when combined with measurements internal to the watershed (such as monitoring at smaller catchment scales and inside catchments), can reveal the underlying processes and their spatial variation. Stream-gauge monitoring of nested watersheds thus generates measurements that appropriately and consistently (and naturally) provide information about spatial variability at each scale.

METHODOLOGY

Our two field locations are near Pullman, WA, within the Missouri Flat Creek watershed of the South Fork of the Palouse River. The Missouri Flat Creek drainage has a long record of study by USGS and WSU scientists. The fields are subject to typical farming practices and crop rotation, receiving N fertilizer during fall and spring planting, and they represent typical bottom-slope, streamflow-generating locations. The undrained field exhibits intermittent winter-spring surface runoff while the tile-drained field does not. These fields represent the principal settings we assume to control streamflow generation and NO_3 discharges.

The tile-drained location was instrumented in 2001 with suction lysimeters (operated at 0.5 bar) and zero-tension pan lysimeters. These samplers were installed horizontally in triplicate at 0.2, 0.5, and 1.0 m depths from a trench (to permit location of sampler intakes beneath undisturbed field soil). They allow us to sample subsurface-pathway events (pans) as well as resident porewater over a range of saturation conditions (suction). In addition, depth profiles of 5 thermistors and 5 TDR moisture probes were installed via the trench wall. Data from these instruments are logged continuously by the weather station (with precip gauge/sampler) located nearby. With this array, we monitor subsurface conditions above a tile drain which drains approximately 10 ha and outlets

10 m distant. The undrained location has soil-water samplers in parallel with the tile-drained location.

Pressure transducers and dataloggers have been deployed and rating curves developed that measure water discharge from nested 660–7000 ha watersheds.

PRINCIPAL FINDINGS AND SIGNIFICANCE

During the reporting period we have extended all of our existing datasets, refined our discharge-estimation procedures such that preliminary N stream fluxes may be estimated, and performed nearly 1500 ^{18}O analyses. Annual nitrate fluxes exiting the watersheds range from 5 to >20 kg (N)/ha, corresponding to approximately 5-20% of typical annualized mean application rates. The ratio of annual nitrate flux to annual runoff *increases* with annual runoff, i.e. larger flows are generally associated with larger N concentrations which typically reach 15-40 mg (N) /L in late February/March. This pattern is different from those observed in humid regions where most such studies have been conducted.

Monitoring of soil water, tile drainage, and ephemeral surface runoff, suggest strong nitrate concentration response to fertilizer application timing in shallow soil and in-field runoff, but not at larger scales. Soil-profile water content dynamics and tile-drain flow rates suggest that high-nitrate soil water is mobilized throughout the profile when water contents near saturation are attained (Figure 1).

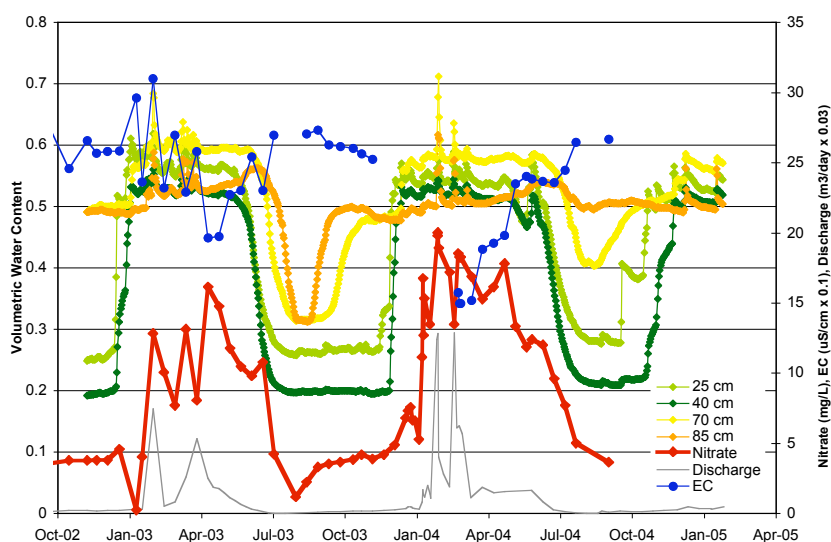


Figure 1. Nitrate and EC concentrations (red and blue respectively) in discharge (gray) from the tile drain. Note relationships of nitrate changes to changes in discharge and shallow soil moisture content (green and yellow). EC is tracer of water-mineral reaction progress and indicates relative subsurface residence time. Low EC values may indicate increased contributions of water from the shallow part of the profile.

This process can explain the generation of high-nitrate seepage and drainage to ditches almost immediately at the onset of high flow, once the antecedent profile is sufficiently wet. High flows also appear to increase contributions of shallow-profile water to runoff by raising water tables, as suggested by temporal behavior of electrical-conductivity values (Figure 1).

The foregoing interpretations do not implicate any sort of subsurface bypass- or preferential-flow processes in the transport of nitrate from point of ground-surface application to discharge in surface water or tile drainage. They are also apparently consistent with vertical soilwater velocities of months to a few years per meter. We are presently studying oxygen-18 temporal dynamics to test these ideas (Figure 2). Tile drainage is apparently “anchored” at a fairly constant ^{18}O value of -15 per mil, indicating substantial filtering and damping of fluctuations evident in the soil profile above the tile drain. However, relatively subtle seasonal fluctuations are also evident in the tile-drain signal. We are presently attempting to apply simple analytical convolution-integral models to these data to attempt to estimate means and ranges (dispersion) of surface-to-drain travel times. We will attempt similar modeling at larger scales.

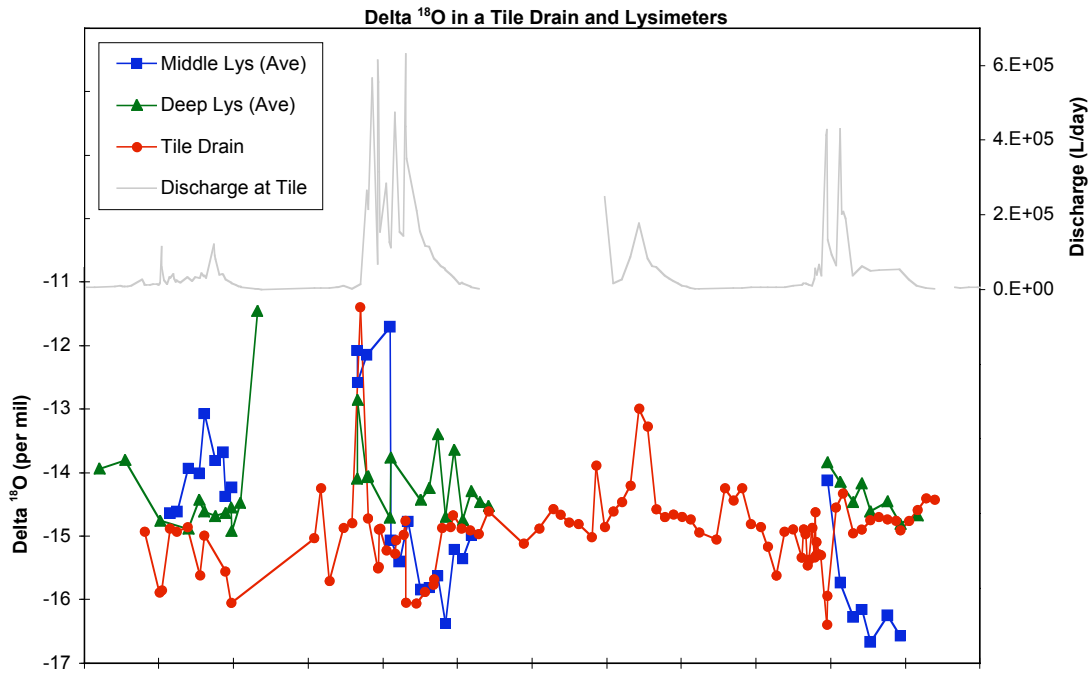


Figure 2. Blue and green symbols represent soil water at 40 and 85 cm depth, respectively. Shallow fluctuations are damped in deeper soil water and tile drainage.